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# CANMET

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

## Coal Research Laboratories

## Laboratoires de recherche sur le charbon

Canada

# COAL PREPARATION ISSUES

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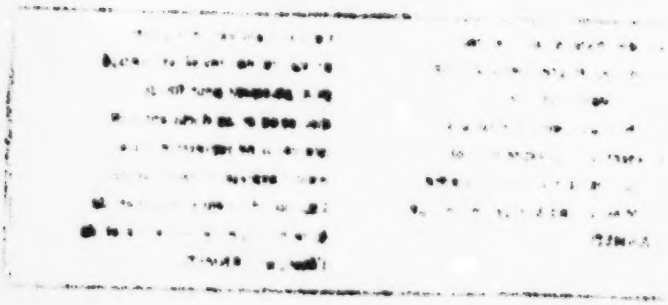

# COAL PREPARATION ISSUES

by

H.A. Hamza*

## ABSTRACT

Fine particles, whether deliberately produced to achieve liberation, as is the case in the mineral industry, or unavoidably generated, as is the case in the coal industry, heavily tax processing and disposal facilities.

Understanding the factors that contribute to the troublesome behaviour of fine particles in solid/liquid systems promise to contribute substantially to their economic processing and safe disposal.

The practical approach to fine particle R&D adopted by the Fuel Processing Laboratory of CANMET, is supported by a strong in-house capability consisting of qualified multidisciplinary team of researchers and state-of-the-art facilities.

This paper draws attention to the importance of fine particle R&D to the mineral and energy industries, briefly outlines FPL's capabilities in this area and gives examples of previous and present contributions to solving industrial problems.

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## RÉSUMÉ

Les particules fines, qu'elles soient produites lors du traitement des minerais triturés, comme c'est le cas dans l'industrie minérale, ou qu'elles soient produites de façon inévitable, comme c'est le cas dans l'industrie du charbon, causent d'importants problèmes de traitement et d'élimination.

La détermination des facteurs qui sont à l'origine du comportement nuisible des particules fines dans les systèmes solides-liquides permettra de réduire considérablement leurs coûts de traitement et de les éliminer de façon plus sûre.

Pour réaliser ses travaux de R-D sur les particules fines, le Laboratoire de traitement des combustibles de CANMET peut compter sur l'appui interne d'une équipe pluridisciplinaire de chercheurs compétents et d'installations de pointe.

Le présent document attire l'attention sur l'importance que revêtent les travaux de R-D sur les particules fines pour les industries minérales et énergétiques, souligne brièvement les capacités du laboratoire dans ce domaine et donne des exemples de contributions passées et actuelles pour résoudre des problèmes industriels.

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## INTRODUCTION

Many of the difficulties facing coal preparation plant operators are not, in fact, dissimilar to those facing their counterparts in mineral processing. These difficulties are commonly associated with processing fine particles.

How fine is fine? The answer usually depends on the nomenclature of the industry involved and on the difficulty of separation resulting from the limitations of the process/equipment.

Fine particle generation in coal is normally considered an unavoidable byproduct that is influenced by the nature of the coal and mining and transportation methods. On the other hand, fine particle generation in the mineral industry is largely a result of the deliberate action of comminution to liberate the particles. In this case, the minimum size aimed at is dictated by the size distribution of the locked valuable mineral and influenced by the nature of the ore amongst other factors such as process limitation and economics.

## FACTORS AFFECTING FINE PARTICLE PROCESSING

It is well known that mineral processing is based on two basic principles:

A. **Liberation** before **separation.**
One has to unlock the "valuable" particles from the matrix before they can be separated.

B. **Removal** of product streams **as soon as they are generated.**

Separation, of course, depends on exploiting chemical and physical differences between the mineral components of the ore. Gravitational forces are the most common and easiest to understand, utilize and control. So are behaviours related to other bulk properties of the mineral/coal components such as magnetic forces.

However, when dealing with very fine particles, the ability to distinguish between particles using differences in bulk properties, especially density, becomes very blurred and it is necessary to use other properties as the basis for separation.

Due to the depletion of high grade ores world wide, poorer grades are being exploited. These are typified by valuable components that are very finely disseminated in a matrix of unvaluable gangue. Therefore, liberation becomes an expensive undertaking. Moreover, finer grinds substantially increase processing costs at all subsequent stages, often requiring larger size plants.

## FINE COAL PROBLEMS

On the coal side, Canada produces approximately 74 Mt/yr by surface mining methods in western Canada and approximately 3 Mt/yr by underground mining methods in eastern Canada. Western Canadian coals span all ranks and have typically <1% sulphur and 15-30% ash; approximately 32 Mt of this coal are beneficiated and are slated mainly for export. Eastern Canadian coals are high volatile bituminous and typically contain 3% sulphur and 10-15% ash; most of this coal (2.5 Mt) is beneficiated (Figure 1).

Western Canadian coals are highly friable and produce large amounts of fines (up to 40%) during mining, transportation and beneficiation. The fines, in this case, are an undesirable byproduct as mentioned earlier. These fines have many deleterious effects on preparation cost and on the environment (dustiness, freezing, effluent disposal, water recycle, etc.). The high proportion of fines in western Canadian coal have greatly influenced the design of existing coal washery flowsheets. Figure 2 shows very clearly the reliance of Canadian coal washery design on fine coal cleaning processes compared to their counterparts elsewhere in the world.

Clean coal losses are highest in relation to fine coal preparation circuits. Table 1 shows that approximately 85% of clean coal losses are mainly attributed to fine coal cleaning circuits with an

associated value of approximately $33M/yr. When one considers the cost of processing these fines (cleaning, dewatering, effluent treatment, tailings disposal, reagents, etc.) the losses actually multiply. Although the data in Table 1 is approximately 10 years old, unfortuntely, it is still considered valid.

Environmental regulations are becoming increasingly stringent regarding releasing such fines to air or water streams. Therefore, extra attention (which is usually translated into extra cost) must be paid to this problem.

## FUEL PROCESSING LABORATORIES (FPL) EXPERTISE IN FINE PARTICLE PROCESSING

It is clear from the previous arguments that treating fines is one of the most pressing problems in both coal and mineral industries. It is worth noting that similar concerns are also shared by the food, pharmaceutical, cosmetic, pesticide, and paint industries.

The importance of the treatment of fines in the processing industries has been realized, for sometime, by FPL. Over the past 14 years, FPL has developed a unique expertise in this area including a multidisciplinary team of researchers and state-of-the-art facilities. These factors led to the development of leading edge R&D in many fundamental and engineering aspects of fines treatment (Appendix).

This expertise defined an important niche for FPL and created many business opportunities. Our present clients include coal, oil, chemical and some mineral industries.

The facilities include laboratory, bench, pilot and field scale instrumentation and equipment. It spans a wide spectrum of activities ranging from molecular structure (surface and colloid chemistry) to large scale engineering experiments.

A unique advantage exists because the scientist and engineer are a part of the same project team and are dealing practically with the same problem/sample using different complementary techniques.

Close working relationships with the industry have been the norm in laboratory (and its predecessors) since being established in the fifties. This close relationship has helped to focus our research and emphasize its relevance.

Our approach to problem solving is illustrated in Figure 3. This approach focuses on finding a solution, starting from the practical end of the spectrum and going into fundamentals only as far as necessary. The project stops as soon as a "reproducible" solution is found. Therefore, fundamental research is used as a tool to solve practical problems and not as an end in itself.

## EXAMPLES OF FPL'S EXPERTISE

The following are examples to illustrate this approach; one from the mineral and one from the energy industries:

### Example 1

Problem:

I. It was required to recover a clear leachate from a pulp produced by a highly alkaline leaching process treating a Ni-Co ore of lateritic origin. Gravity settling/clarification was the process of choice. However, the settling/clarification rate was extremely slow due to the very fine nature of the solids (78% < 30μm).

II. It was also required that the solution be compatible with 6-7 counter current washing cycles (Figure 4).

Solution:

It was decided that flocculation was the most practical/economical approach. Since the solids included magnetic particles, both magnetic and chemical flocculation were investigated. Figure 5 shows that the untreated pulp had a settling rate of only .01

in/h. Magnetic flocculation improved the settling rate to .05 in/h. Chemical flocculation improved the settling rate to 1.06 in/h. However, in the latter case, the leachate was still turbid. A combination of magnetic and chemical flocculation gave a settling rate similar to that produced with chemical flocculation but with a very clear leachate.

It is evident that flocculation improved the settling rates many fold. This is obviously translated into a reduced settling area (smaller equipment size) and lower operating costs (maintenance, temperature control, especially in winter, etc.). The required unit settling area was reduced from 1600 $ft^2$/tpd for the untreated pulp to 320 $ft^2$/tpd for the magnetically flocculated pulp and further to 13 $ft^2$/tpd when the combination of chemical and magnetic flocculation was used.

Selecting the most suitable flocculant was not an easy task due to the "harsh" nature of the pulp. However, the main problem was to find a flocculant compatible with multiple counter current washing. Specifically, the required flocculant should be able to resist degradation due to repeated pumping and be less sensitive to variations in pulp properties during counter current washing.

Flocculation is effected by a long thread-like chain of organic water soluble molecules. Each molecule consists of a backbone and numerous hair-like "active" whiskers distributed along the backbone (Figure 6). These active groups have very high affinity to specific adsorption sites on the surface of the solid particles. The flocculant molecule can attach itself to a number of sites and to several particles joining them in an aggregate called a "floc".

Problems arise when the floc is broken, as is the case when the thickened pulp is transferred by pumps from one stage of washing to the next. The breakage in this case is irreversible since it occurs along the backbone of the flocculant molecule rather than detaching the molecule from the solid particles. The remnants of the molecules that are left freely dangling in the solution have the tendency to coil back and adsorb on the same particle to which they were attached. Therefore, more adsorption sites on the particle are rendered inactive.

As this process is repeated more and more individual particle surfaces become covered with flocculant without being included in aggregates. The particle surface becomes virtually a new surface with different properties. This process will deteriorate the effectiveness of the selected flocculant and consequently will drastically reduce settling rates.

When a laboratory simulation of the multiple washing regime was studied, it showed that the settling rate deteriorated rapidly as washing progressed (Figure 7). It also showed that the effectiveness of flocculation can be restored when a second appropriate flocculant is applied. This flocculant "sees" the flocculant-covered particle surface as a new surface possessing properties different from the original particle surface.

Example 2

Problem:

It is required to settle/consolidate sludge from tarsands tailings into settling ponds, possibly recycle, or safely dispose of, the water and recover residual bitumen.

The amounts of sludge generated are enormous, 50,000 $m^3$/day for every 22,000 $m^3$/day of bitumen produced. The settling of the sludge is almost negligible in any reasonable time frame. This situation necessitated dumping this material in huge tailing ponds (one tailing pond is currently covering an area of 23 $km^2$).

Solution:

This project has just started, therefore it is too early to speculate on solutions. However, it is felt that studies of the physico-chemical structure of the sludge may lead to an understanding of the cause of its extreme stability and eventually to an engineering solution.

Some of the preliminary studies carried out so far indicate that the sludge forms a uniform well-defined structure that traps the water. Unless this structure is destroyed the water may not be liberated. FPL developed a technique to study "fluid" samples under SEM. This technique involves a quick freeze-fracture procedure that preserves the integrity of the sample allowing for both morphological and chemical (x-ray) examination. More recently a technique of slow sublimation of the water in the sample undergoing electron microscopy has been developed. Figure (8a) shows a sample of the natural sludge while Figure (8b) shows the same sample, after entrapped water sublimation. Figure 8b reveals the uniform, well defined structure of the sludge clays.

Other rheological studies confirm this preliminary finding and point out the gel-like nature of the sludge.

Example 3

There are numerous examples of work done jointly and on behalf of the coal industry in western and eastern Canada. One of the most recent projects was done on behalf of the coal industry in British Columbia and Alberta.

Problem:

FPL was required to evaluate the potential of spiral separators in cleaning fine coals.

Solution:

The efficiency separation was evaluated as compared to the established technique of water-only cyclones which supposedly cover the same range of particle size as the spirals.

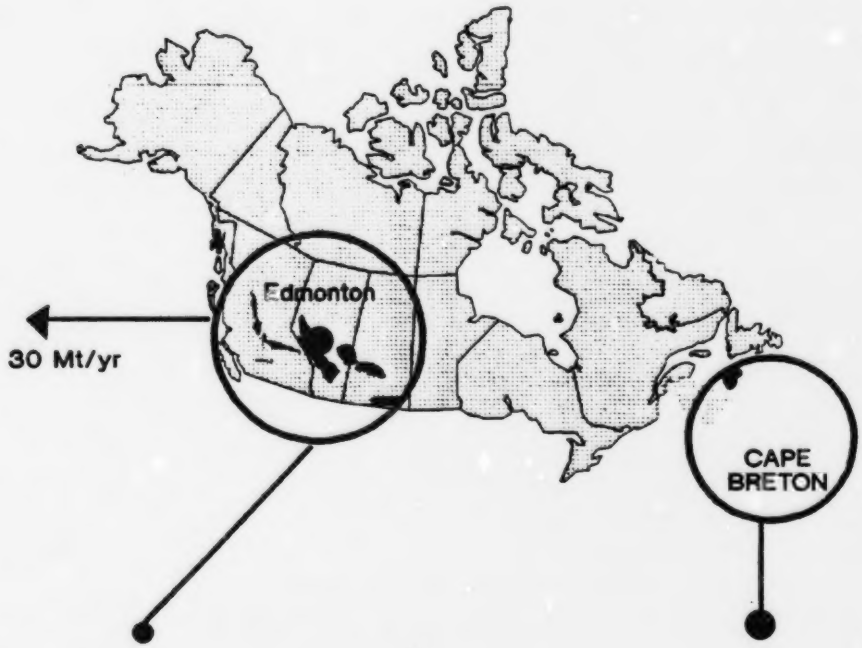
FPL's work concluded that a single spiral can achieve comparable separation efficiency to a two-stage water-only cyclone

but with less control on the quality of the clean coal ash. Also spirals separates finer particles (less than 0.15 mm) more efficiently than the water-only cyclone. The spiral also can tolerate increase in percent of very fine particles (e.g. clays) with no effect on separation efficiency. The recommendation to the industry was to run single-stage water-only cyclone to give low ash clean coal instead of two-stage presently in use, followed by a single-stage spiral. This will improve the efficiency of the circuit and give relatively low ash clean coal and higher ash in reject than presently produced.

## CONCLUSIONS

The payoffs resulting from finding solutions to fine particle problems associated with the mineral and energy industries could be substantial in terms of economic and environmental impacts.

FPL's unique expertise and facilities can significally contribute to finding solutions to industrial fine particle treatment problems. FPL is prepared to work with client industries to achieve solutions and more importantly, to market and apply technologies developed.




| SURFACE MINING | UNDERGROUND MINING |
|---|---|
| 74 Mt/yr | 3 Mt/yr |
| All Ranks | High Volatile Bituminous |
| <1 Per Cent Sulphur | 3 Per Cent Sulphur |
| 15 - 30 Per Cent Ash | 10 - 15 Per Cent Ash |
| 32 Mt/yr Beneficiated | 2.5 Mt/yr Beneficiated |

Fig. 1. Major Coal Deposits in Western and Eastern Canada Showing location CRL, Edmonton and CRL, Cape Breton

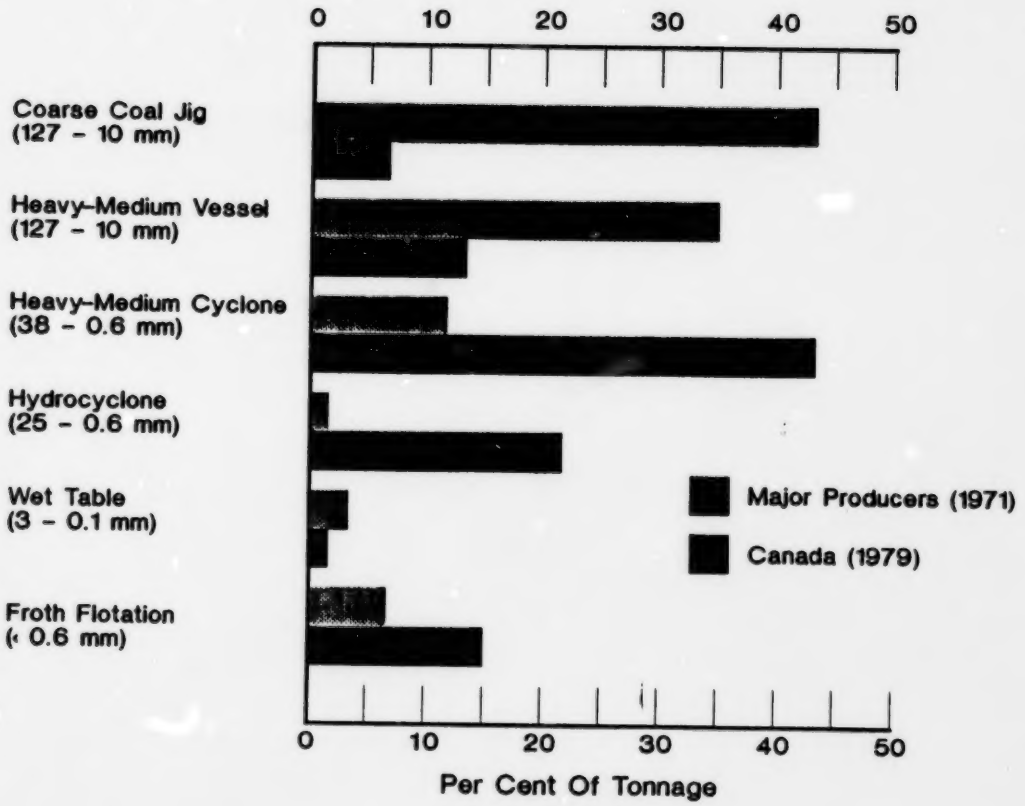



Fig. 2 Comparison of process use in Canada and other major coal-producing countries (CANMET REPORT No. 85 - 2E, Mar 1985, J.L. Picard).height

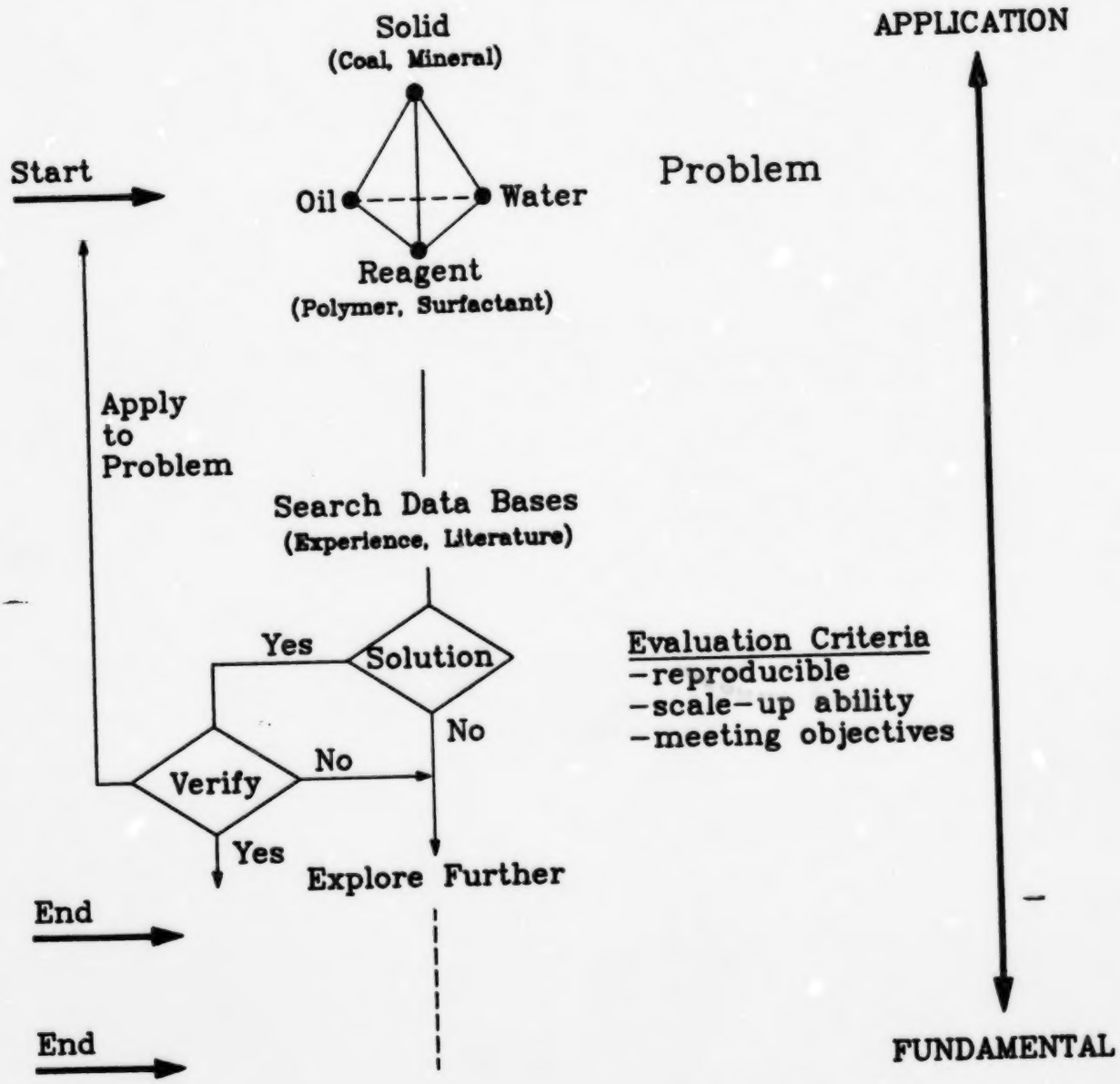



Fig. 3 FPL's Approach to R & D

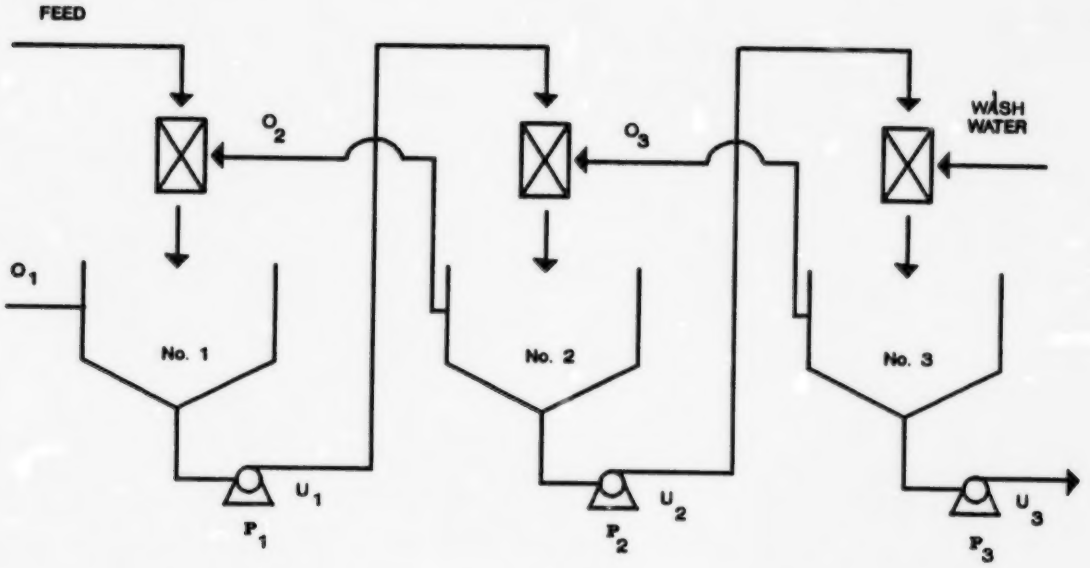



Fig. 4 Counter Current Washing of Pulp.

(O = Overflow; U = Underflow; P = Pump)

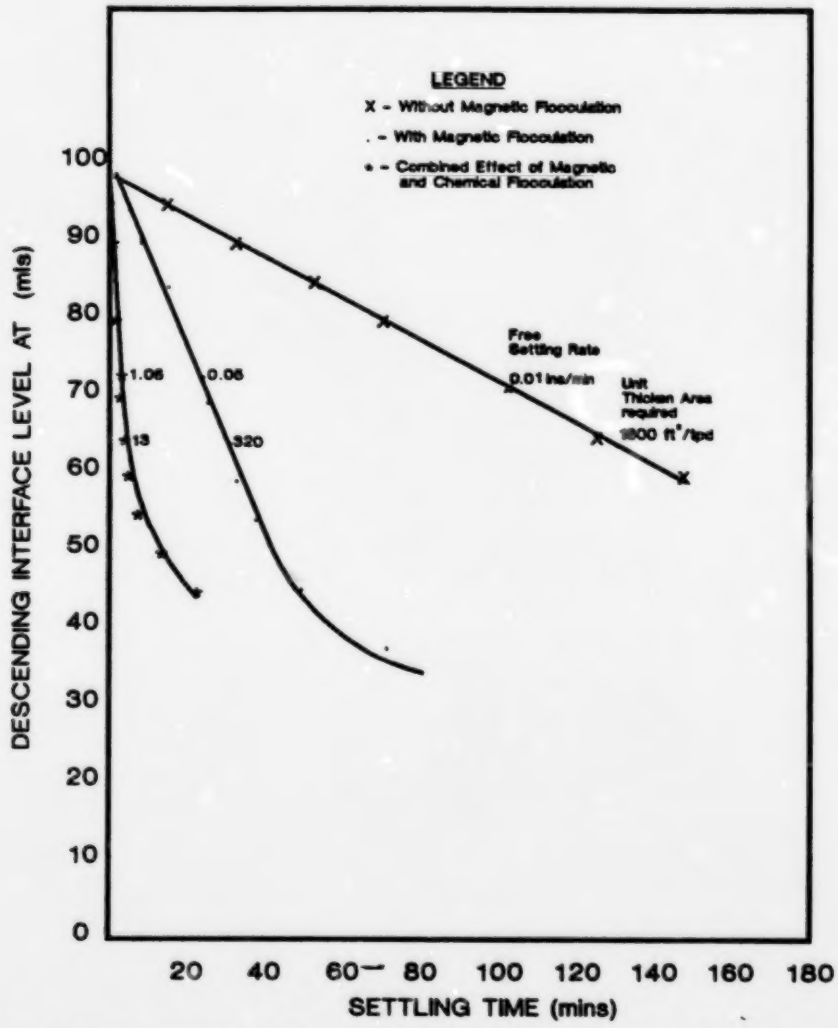



Fig. 5 EFFECT OF MAGNETIC FLOCCULATION ON SETTLING RATES

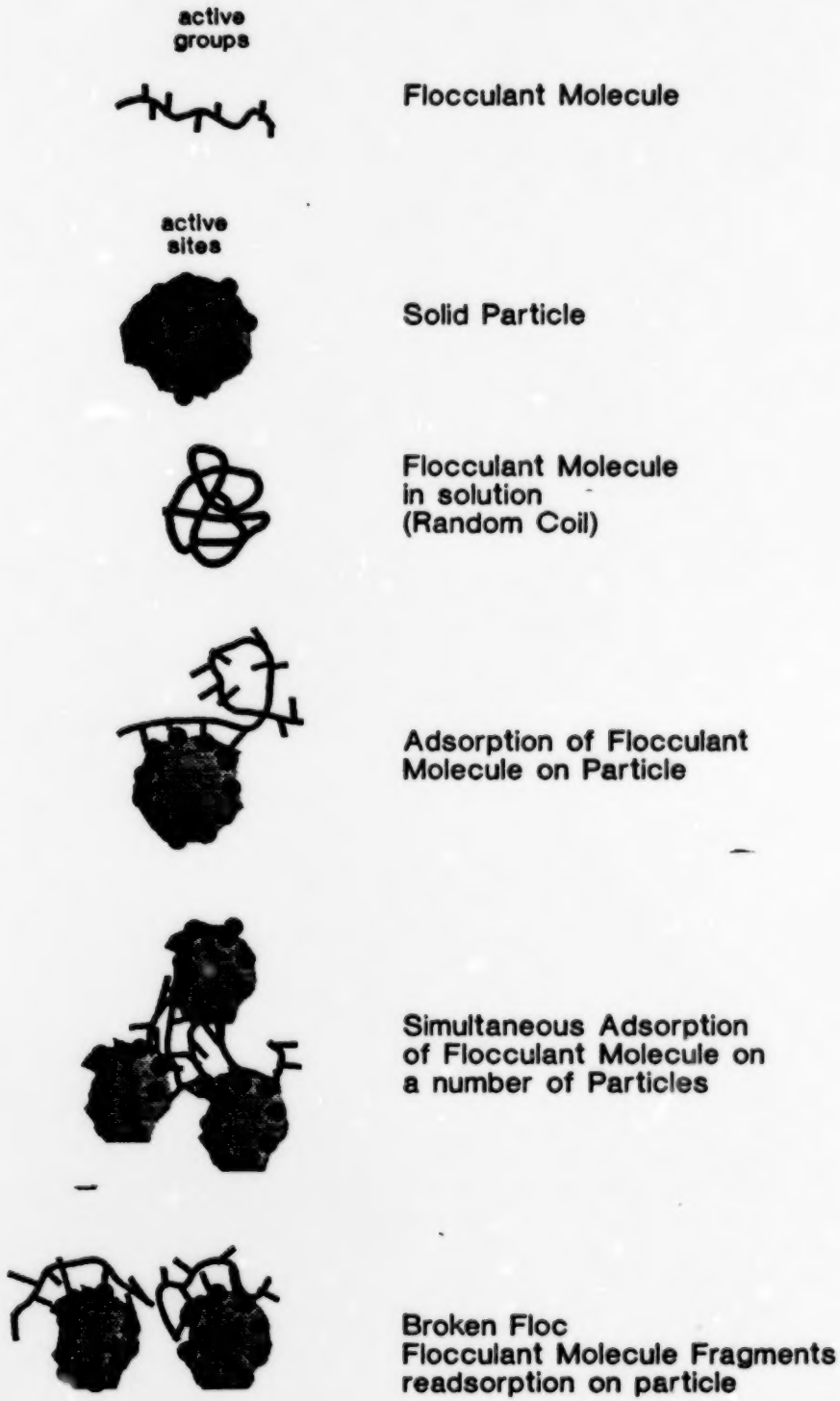

active groups
Flocculant Molecule
active sites
Solid Particle
Flocculant Molecule in solution (Random Coil)
Adsorption of Flocculant Molecule on Particle
Simultaneous Adsorption of Flocculant Molecule on a number of Particles
Broken Floc
Flocculant Molecule Fragments readsorption on particle

Fig. 6 Schematic of Flocculantion Process

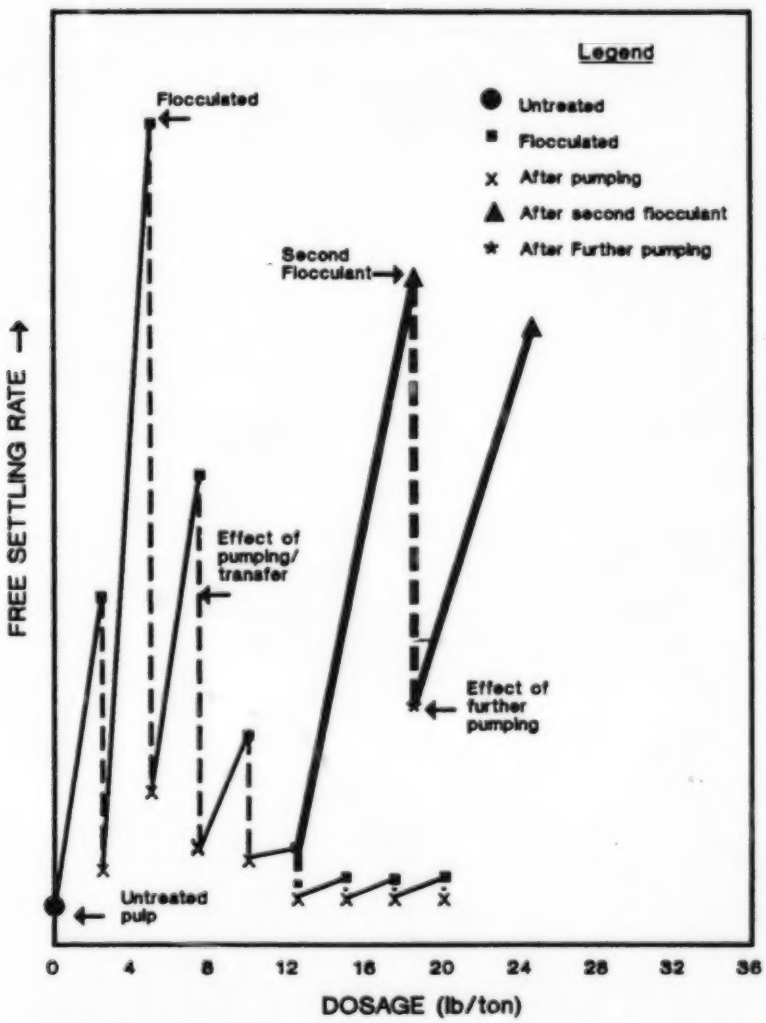



Fig. 7 FLOCCULANT SATURATION CHARACTERISTICS

(AS A RESULT OF REPEATED LEACHING-FLOCCULATION-SETTLING-PUMPING CYCLE)

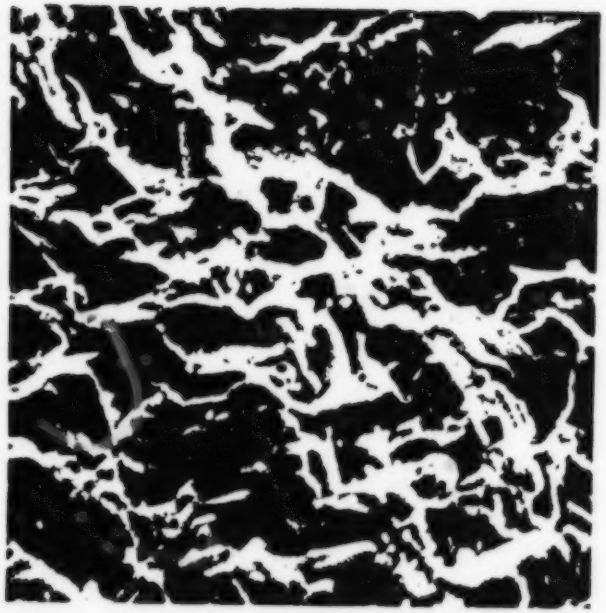


Figure 8a

SEM micrograph of freeze-fractured sludge sample. The presence of water makes determination of any clay-oil structure difficutlt.

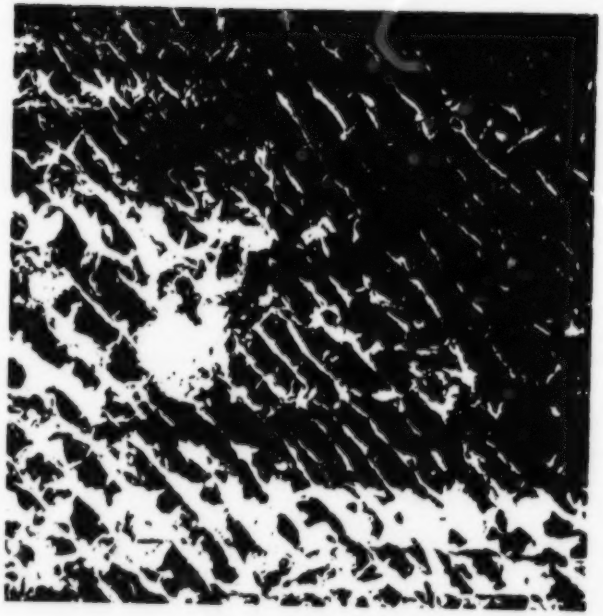


Figure 8b

SEM micrograph of freeze-fractured sludge after sublimation of water. The clay-oil structure which makes this sludge difficult to de-water is clearly evident.

Table 1 – Distribution and estimated value of clean coal loses annually during 1978–80 (CANMET REPORT NO. 85 -2E, Mar 1985, J.L. Picard).

| Process | Size range (mm) | Net clean coal losses | | Estimated* value ($000) |
|---|---|---|---|---|
| | | tpa | % | |
| Coarse Coal Jig | 127–10 | 10 790 | 1.4 | 507 |
| Heavy-medium vessel | 127–10 | 33 490 | 4.2 | 1 574 |
| Heavy-medium cyclone | 38–0.6 | 44 065 | 5.5 | 2 071 |
| Hydrocyclone | 25–0.6 | 28 415 | 3.6 | 1 335 |
| Concentrating table | 3–0.1 | 77 000 | 9.7 | 3 619 |
| Hydrocyclone | 0.6–0.1 | 289 710 | 36.3 | 13 616 |
| Froth flotation | 0.6–0.1 | 312 900 | 39.3 | 14 706 |
| Total | – | 796 370 | 100.0 | 37 429 |

* Based on $47 per tonne

# APPENDIX

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